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Developing the Sandia National Laboratories Transportation Infrastructure for Isotope Products and Wastes

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The U.S. Department of Energy (DOE) plans to establish a medical isotope project that would ensure a reliable domestic supply of molybdenum-99 (^{99}Mo) and related medical isotopes (Iodine-125, Iodine-131, and Xenon-133). The Department's plan for production will modify the Annular Core Research Reactor (ACRR) and associated hot cell facility at Sandia National Laboratories (SNL)/New Mexico and the Chemistry and Metallurgy Research facility at Los Alamos National Laboratory (LANL). Transportation activities associated with such production is discussed.

BACKGROUND

A sufficient supply of certain radioactive isotopes is critical to numerous patients and the medical community serving them in the United States and other North American countries. The most important medical isotope is ^{99}Mo , which is used nearly 80 percent of the time in nuclear medicine diagnostic procedures. The isotope technetium-99 ($^{99\text{m}}\text{Tc}$), which is the decay product of ^{99}Mo , is a medically attractive isotope in its metastable form. The metastable state of a nucleus is at a higher energy potential than the ground state (Chase and Rabinowitz 1968). It is this phenomenon that produces gamma rays upon transition that is so useful in medical imaging for diagnosis. The radiation decay characteristic peak at 140 keV provides an energy which can pass out of the body and is within the window of efficient detection for compatible detectors. The half-life of $^{99\text{m}}\text{Tc}$ is about six hours, making it a very useful, yet perishable, commodity.

Production loss possibilities prompted the U.S. Congress to direct the DOE to provide for a U.S. backup source for this crucial isotope. Nordion International, Inc. of Canada currently manufactures ^{99}Mo in an aging reactor a few years from the end of its useful life. The reactor is operated by Atomic Energy of Canada, Ltd. SNL was selected for medical isotope production as a new realm of manufacturing for the laboratory. At the manufacturing stage, SNL would expect to service up to 30 percent of the U.S. market

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under normal circumstances, with the capability to service 100 percent based on need. With the ^{99}Mo demand increasing each year, the project would guarantee the continuing supply of needed medical isotopes.

The project comprises fabrication of isotope production targets and LANL followed by irradiation in the SNL ACRR. The irradiated targets would be moved to the adjacent hot cell facility (HCF) for processing, where the radioisotopes of interest would be separated from the fission products. The short half-life product, ^{99}Mo in NaOH, would then be sent air freight to radiopharmaceutical (RP) manufacturers. Waste generated during the fabrication process would be temporarily stored on-site and subsequently disposed of at proper waste facilities.

A COMPLEX ISOTOPE PRODUCTION PROCESS

A diagram of the ACRR is shown in Figure 1. The reactor core is installed in a large open tank filled with about 10 m (33 ft.) of water to provide natural convection core cooling and radiation shielding. The water pool is cooled by an external heat exchanger. The ACRR currently operates in either a pulsed or steady-state mode. The current steady-state power limit is 2 megawatts (MW). With installation of additional heat exchanger/cooling tower, heat rejection capacity would allow the reactor to run up to 4 MW steady state.

Configurations of up to 19 or 37 targets at a time are planned. Targets consist of stainless-steel tubes as shown in Figure 2, containing highly enriched uranium-235 (^{235}U) as a layer of uranium oxide (U_3O_8) approximately 5.0×10^{-5} m (50 microns) electroplated onto the inside surface of the tube. They will be irradiated to provide a range of fission products including isotopes of molybdenum, xenon, and iodine. Targets irradiated for several days would be removed from the core and transferred via pass-through ports to a rack in the Gamma Irradiation Facility (GIF) pool (see Figure 1). A transfer cask would be lowered into the GIF pool and the irradiated target(s) would be loaded into the cask and transferred to the HCF.

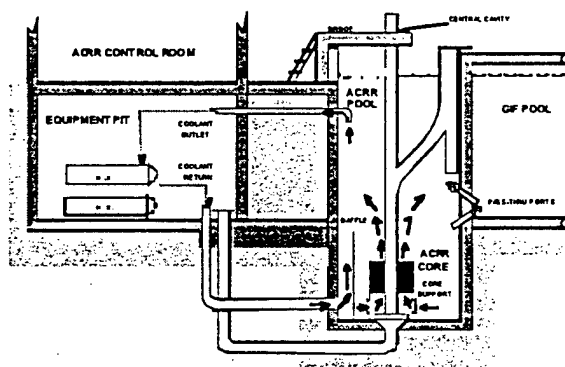


Figure 1. ACRR Reactor Tank

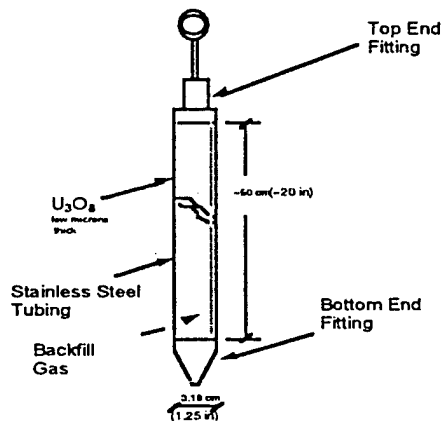


Figure 2. Target Design

The HCF is being reconfigured to accommodate the addition of new Steel Confinement Boxes (SCBs) that would result in safer, more reliable, and more versatile irradiated target processing operations. New SCBs are designed to provide complete process control, including waste minimization and management.

The irradiated targets, each containing almost 741 TBq (20 kCi) of fission products, would be processed within the SCBs. Isotopes of interest would be extracted from fission products by chemical dissolution and precipitation procedures. Molybdenum would be precipitated, filtered, and cleansed; and the precipitated molybdenum would be redissolved for shipment to pharmaceutical companies. ^{99}Mo is the isotope of initial interest; however, ^{131}I and ^{133}Xe may be directly extracted from the processing line as additional medical-valued products. The isotope ^{125}I may also be produced by irradiation of ^{124}Xe , a nonradioactive isotope of xenon.

Each target would yield up to 30 TBq (800 Ci) of ^{99}Mo , 7.4 TBq (200 Ci) of ^{131}I , and 22 TBq (600 Ci) of ^{133}Xe six hours after removal from the reactor. The isotopes would be further purified to meet U.S. Food and Drug Administration (FDA) Drug Master File (DMF) standards. The isotopes would then be properly packaged and shipped in shielded casks by air freight to RP companies. Approximately 20 to 25 targets per week can meet 100 percent demand with proportionately less targets for the anticipated level of 30 percent U.S. demand.

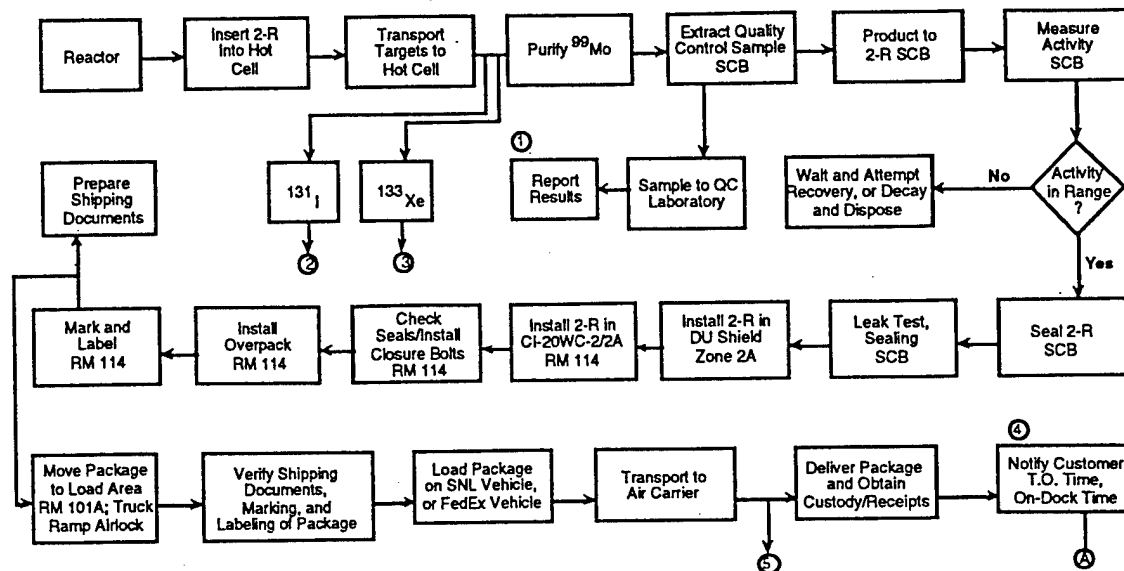
About one-half liter (~ 1 pint) of neutralized process liquid (waste) would be generated per target. This liquid would be solidified, allowed to decay, and then shipped to an approved low-level waste disposal facility. Although shipments to the disposal site could be made as soon as six months after generation, sufficient storage exists within the HCF to allow up to two years storage of waste generated as a result of meeting 100 percent of U.S. demand.

TRANSPORTATION INFRASTRUCTURE

The transportation infrastructure is the recognition of necessary functions and the assemblage of people, materials, and processes that culminate in the capability to safely ship isotope products from the SNL production site the RP manufacturers facility. The flow diagram shown in Figure 3 reflects a portion of the infrastructure.

After the isotope product has been made, the transportation process begins in the hot cell facility with the loading of the product into the 2R container--the innermost packaging component. Following the product bottle loading, the 2R is closed, and a pre-shipment leak test is performed by using a vacuum system to reduce the pressure in a bell jar to one-half atmosphere. The 2R is then loaded into the next packaging component, a depleted uranium (DU) radiation shield. This assembly is moved from the hot cells to an

adjacent room where it is loaded into the 20WC packaging and closed for shipment. Radiation readings are taken to assure an accurate Transportation Index is applied.



- ① QC report must be received prior to customer receipt of product. ②, ③ Diagrams to be developed. ④ Notify customer of QC results.
 ⑤ Prearrange shipping payments.
 SCB - Steel Containment Box
 DU - Depleted Uranium
 2R - Inner Containment Vessel

Figure 3. Packaging Flow

Because this facility is located in a highly secure area, the package must be sealed and accounted for upon its movement outside the secure area to meet with the cargo air carrier.

The infrastructure also includes the interface with the shipper through the SNL Logistical Department, and the coordination required by the RP manufacturer. To provide assurance for any accident or incident concerning shipments, the project is covered by an emergency response plan that mobilizes the proper organizations to deal with such problems. Capability is maintained for quick reaction at the reactor area on Kirtland Air Force Base (KAFB), and when packages are under control of the shipper, both local and state resources are available.

When the project matures to a point where significant amounts of product are shipped, the infrastructure may change to include both KAFB and the international airport (Sunport) roadways, since they can be linked to provide a path to the airport freight area without going onto public roads.

To achieve this flow process, the infrastructure must include security personnel, health physics specialists, the logistical team composed of a packaging consultant and packers, as well as the HCF personnel. A degree of training is required for the persons performing each of these functions. Certain training is specified by U.S. regulations; for instance, Radiation Worker and Hazardous Material Employee. Other training that must be accomplished includes the specific HCF procedures for transportation functions and the packaging specific training that culminates in proper packaging assembly and disassembly operations. Other aspects of training include the correct usage of both periodic maintenance helium mass spectrometer and the SNL manufactured pre-shipment leak test device.

Because of the age of the product packaging, they have become a focal point within the infrastructure and much resource has been expended to keep them viable.

Table 1 shows the general characteristics of the two types of packages that will be used in the Isotope Production Project (IPP) to transport product. The DOT- and NRC-certified Type B (NRC 1993a) package designated for use in transporting ^{99}Mo and ^{131}I is the CI-20WC-2 and -2A model (NRC 1993b). The primary difference between the two models is the size and the amount of shielding. Both CI-20WC (Figure 4) models are described as follows: steel encased, wooden outer protective jackets with a depleted uranium shielded cask, and inner steel containment vessel. The protective jackets are contained within an 18-gauge steel drum. The inner containment vessel is a small 416 stainless-steel gasketed and threaded container. The contents type and form of material for which the packages are certified are: $^{99}\text{Mo}/^{99}\text{Tc}$ in normal form as solids or liquids with a maximum quantity of material per package of 37 TBq (1 kCi), and ^{131}I in normal form, or liquids with a maximum quantity of material per package of 7.4 TBq (200 Ci).

Table 1. Type B Package Characteristics

| | Product | | Waste | Spent Fuel |
|--|--|--|---|---|
| Characteristics | CI-20WC-2 | CI-20WC-2A | B-3 | BMI-1 |
| Cavity Diameter | 3.1 in. (7.95 cm) | 3.1 in. (7.95 cm) | 26.5 in. (67.95 cm) | 15.5 in. (39.74 cm) |
| Cavity Length | 6.0 in. (15.38 cm) | 6.0 in. (15.38 cm) | 43.25 in. (110.9 cm) | 54.0 in. (138.46 cm) |
| Shielding | 2.2 in. (5.64 cm) DU + .35 in. (.9 cm) Steel | 1.95 in. (5 cm) DU + .95 in. (2.43 cm) Steel | 6 in. (15.38 cm) Pb + 1.25 in. (3.2 cm) Steel | 8 in. (20.51 cm) Pb + .87 in. (2.23 cm) Steel |
| Weight, Empty | 440.5 lb (200.2 kg) | 314 lb (143 kg) | 21,000 lb (9,545 kg) | 21,860 lb (9,936 kg) |
| Note: The surface dose rate limit is 200 mrem/hr (2mSv/hr) for all packages. | | | | |

The larger CI 20WC-2 packaging population has been depleted due to corrosion and other effects that occurred during their lengthy service life with Cintech Corp. Many of

them remain, but several have been removed from service. Fortunately, the smaller CI 20WC-2A packagings are in better condition and are expected to sustain longer service. Both of these packagings are Nuclear Regulatory Commission Type B(), or "grandfather" packagings. They can be maintained, but new components and major work cannot be done to them. The NRC certificate packagings do, however, retain a Department of Transportation (DOT) Certificate of Competent Authority (CoCA) that allow their use internationally. Some of the packagings can also be used as DOT specification packages, but the CoCA for them has expired and they would only be used domestically. Packaging for ^{133}Xe will likely be a Cintech-designed Type A gas cylinder. The package for ^{125}I has not been determined.

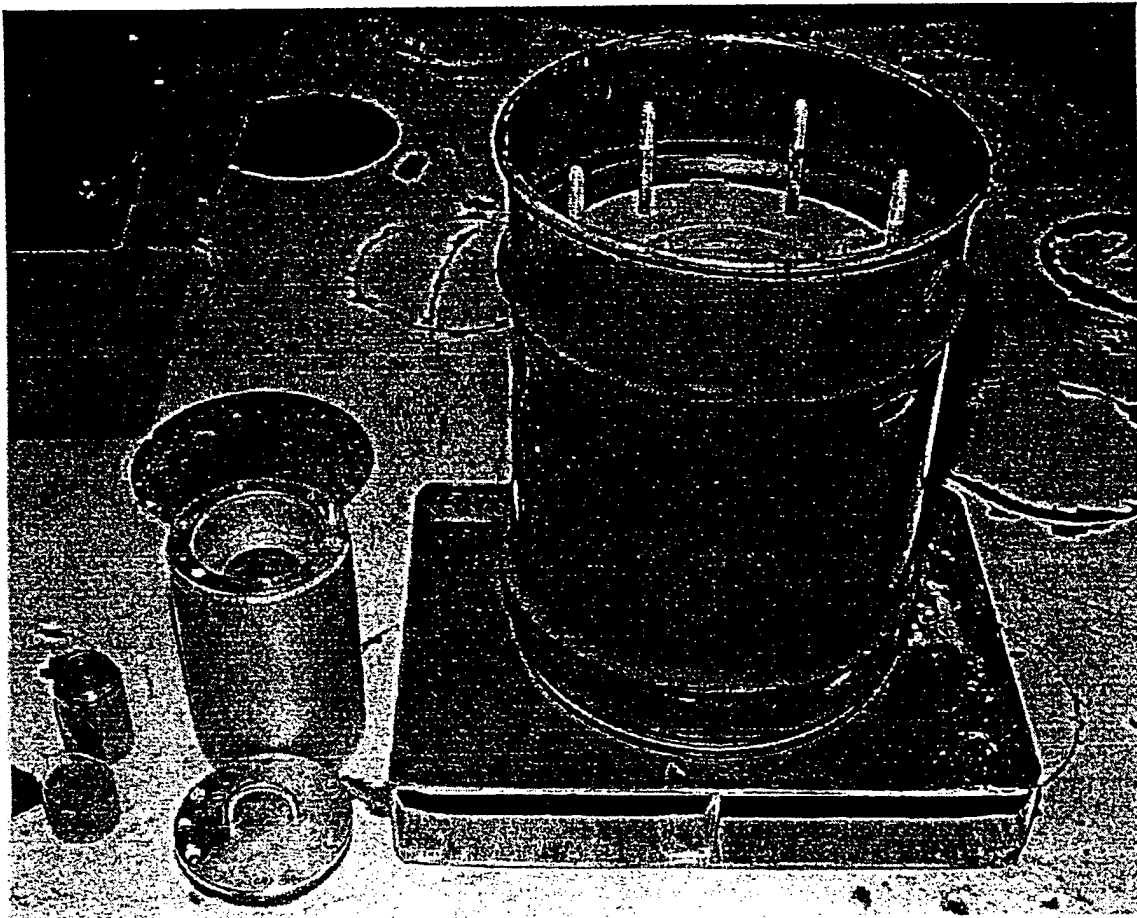


Figure 4. CI-20WC Transport Package

PACKAGE ASSEMBLY AND SHIPPING REQUIREMENTS

Isotope ^{99}Mo decays at the rate of about one percent per hour. Shipment of the product must be rapid to prevent needless decay of the product.

We expect to ship up to 30 Tbq of ^{99}Mo per processed target and about six to seven packages per week at the nominal 30 percent production level. The ^{99}Mo product will be

pharmaceutical quality and an FDA DMF will be existent for its production. At the present time, ^{131}I and ^{133}Xe have DMFs and their shipment initially would likely occur for sampling purposes. The ^{99}Mo is expected to be shipped initially on a daily basis to one of three different locations: St. Louis, Chicago, and Boston. Air freight express class of shipments are envisioned. Product movement from the TA-V reactor area to the airport transfer point using Kirtland Air Force Base and Albuquerque International Sunport access roads is the preferred route, avoiding public roads. Quality assurance (AQ) may occur during the time the product is in shipment.

Current infrastructure improvements at SNL involves adding packaging to the stockpile, developing means to rapidly receive empty packaging and turn them around for immediate reuse, and studying the infrastructure components for both improvements and simplification. Future aspects of loading, handling, and movement of both product and waste containers could address needs for modernized containers that are suitable for automation. Minimizing the human element in operations will lead to improved efficiency and safety. Other enhancements such as real-time cask identification and radiation survey, for instance, would enhance efficiency and responsiveness of the infrastructure.

WASTE PACKAGING AND SHIPPING

The package designated for transportation of process waste is the NRC-certified B-3 Type B package (NRC 1990). The packaging consists of a 15.38 cm (6-in.) lead shielded steel weldment in the shape of a right hollow cylinder with a bottom and a recessed, plug-type gasketed and bolted lid. Packaging features include lifting and tie down devices and a drain to the central cavity. The maximum weight of the loaded package is 30,000 lb (13,636 kg).

The primary waste disposal site designated for production and laboratory wastes is the Nevada Test Site facilities north of Las Vegas, Nevada. The site is compatible for these classes of waste and the site is operational. Two alternative waste disposal facilities are located at the Hanford Site near Richland, Washington. One truck would carry one B-3 package per shipment. The shipments would go directly from the ACRF building to the primary site or to either alternative site along the most direct route chosen by the motor transport company. Approximately 85 shipments per year will be required.

CONCLUSION

The growing importance and versatility of nuclear medicine are but a few of the reasons for an expanding market, both in the United States and worldwide. As populations continue to grow, so will the need for nuclear medicine. New combinations of radionuclides and medical substances are increasing the spectrum of RPs available to the medical community. Concurrently, as the technology is expanding, the number of

countries acquiring such technologies is expected to increase, perhaps dramatically. A sharply increased demand by the RPs could result in direct proportion. Thus, proper packaging and a streamlined transportation infrastructure will be necessary.

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